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Original Research

Effect of Fed State on Self-selected Intensity and Affective Responses to Exercise Following Public Health Recommendations

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ABSTRACT

International Journal of Exercise Science 12(2): 602-613, 2019. Nutritional status has numerous effects on exercise metabolism and psychological responses. The effect of fed state on changes in affective valence; however, are unknown. Thus, the present study examined how fed state influenced self-selected exercise intensity, affective responses during exercise, and exercise enjoyment when exercise was completed following physical activity guidelines for public health. In a repeated-measures crossover design, 25 recreationally active men and women (age and BMI = 22.0 ± 2.0 yr and 24.3 ± 3.3 kg/m^2) performed a single 30 min session of treadmill exercise at a Rating of Perceived Exertion (RPE) equal to 13 on the Borg 6-20 scale following an overnight fast (FAST) or 30 minutes after a small meal (FED). Affective valence was recorded every 3 minutes during exercise. Heart rate and gas exchange data were measured continuously using a metabolic cart, blood glucose and blood lactate concentration were measured pre/post-exercise, and enjoyment was measured 15 minutes post-exercise. There was no effect of condition on affective valence, enjoyment, or self-selected intensity (all $p>0.05$). However, pre-exercise blood glucose was higher in FED pre-exercise, but higher post-exercise in FAST ($p<0.05$). Blood lactate concentration was also higher in FAST ($p<0.05$). Our results reveal minimal effects of a small, high-carbohydrate pre-exercise meal on in-task and post-task affective responses, exercise enjoyment, and self-selected intensity. These data suggest that an overnight fast does not alter affective valence or reduce enjoyment of continuous exercise.

KEY WORDS: Fed, fasted, exercise, affect, enjoyment

INTRODUCTION

It is evident that obesity rates have increased worldwide, and that obesity is a risk factor for several chronic diseases (9, 32, 33). Much attention has been given to the relationship between the development of cardiovascular disease (CVD) and modifiable risk factors such as obesity, diabetes, and physical inactivity (26). Furthermore, compelling evidence now exists that increases in cardiorespiratory fitness can reduce or even eliminate mortality risk of other CVD risk factors (18, 25, 27). In light of current health issues, physical activity is heavily promoted to ameliorate disease risk. However, existing guidelines suggest anywhere from 150-300 minutes per week of moderate-vigorous physical activity (MVPA)(19), which may be a significant barrier to adherence due to the extensive time commitment, as fewer than 5% of individuals from a nationally representative sample achieved 30 minutes of activity per day as assessed via accelerometry (45).

Many behavioral interventions operate under various psychological theories (e.g., social cognitive theory, theory of planned behavior) that posit humans will make decisions rationally based on the available information (16), but if this was the case, clearly more people would engage in physical activity and adhere to exercise programs, given the overwhelming amount of data which show the health benefits of MVPA (14). Therefore, some experts have expressed that the hedonic theory of motivation should become the predominant structural theory for physical activity behavior (14, 15). Hedonic theory states that individuals will do what makes them feel good and will avoid what makes them feel worse. More specifically, in psychological hedonism, the overlying theory states that behavior is motivated by the desire for pleasure and avoidance of displeasure, which can occur immediately or in the long term (31) and can be related to sensations (such as pain from an injury) or attitudes and emotions (pleasure of pride/accomplishment) (42). For example, affective responses to an acute exercise bout predicted physical activity 6 and 12 months later (47). These authors' results suggested that a one unit increase in scores on the Feeling Scale (a single-item measure of the valence dimension of affect, -5 to +5, very bad to very good, 20) was associated with an additional 38 and 41 minutes of physical activity per week 6 and 12 months later, respectively. These data are supported by the conclusions of a recent review that found affective responses during exercise were predictive of exercise behavior; however, post-exercise affective valence (valence is the positivity or negativity theorized to motivate approach or avoidance of an event or situation) was not (36). Thus, any strategies to improve experienced pleasure experienced during exercise adoption and training could be crucial for long-term exercise adoption, physical activity adherence, and weight control.

It has been demonstrated that ingestion of nutrients such as carbohydrate and caffeine before and during exercise can improve affective valence and exercise enjoyment compared to water or placebo, and may also enhance work completed at a fixed or self-selected intensity during moderate or high-intensity exercise (1-3, 34, 41). However, eating pre-exercise may elicit gastrointestinal issues, which could increase perceived exertion and have negative consequences on affective valence and exercise enjoyment (12, 35), although this link is speculative and remains to be established.

An alternative to exercising in a fed state might be to exercise fasted, such as exercising upon waking without food intake. Exercising fasted has been shown to increase fat utilization during and up to 24 hours after exercise, which could be beneficial for weight loss (21, 22, 46). In addition, training in the fasted state elicits beneficial molecular adaptations promoting fat utilization (7, 11), and , when incorporated into a training regime, may improve athletic performance (28, 29). However, exercising in a fasted state also can have negative impacts on blood glucose concentration, which may impact affective responses and compromise self-selected intensity.

Therefore, the purpose of the present study was to examine how manipulation of fed state impacts self-selected exercise intensity, affective valence, and exercise enjoyment during exercise in accordance with current exercise prescription guidelines for adults (19). We hypothesized that a higher self-selected intensity and improved mood responses would be observed in the fed state versus the fasted state. Results of the current study will be of interest to practitioners and the general public and have implications for meal timing around exercise to optimize the perceptual response to physical activity.

METHODS

Prior to participant recruitment, the Institutional Human Subjects Review board reviewed and approved this study (Human Subjects Protocol #1123067-1). All participants provided informed consent before completing any aspects of the study. The present study was a randomized, crossover study. The study consisted of two conditions, FAST and FED. Upon arrival to the laboratory after an overnight fast, participants consumed 12 ounces of water (FAST) or ingested a small (180 kcal) carbohydrate rich (39 g CHO) meal (Quaker Chewy granola bar, PepsiCo, Barrington, IL, USA; 12 oz Gatorade, PepsiCo, Barrington, IL, USA) (FED). Thirty minutes later, participants exercised on a treadmill for 30 minutes at a self-selected intensity corresponding to an RPE of 13 (5). They were free to adjust the speed/grade as necessary to maintain this intensity, and every 3 min, the RPE scale was shown to them to ensure that they maintained this intensity. Trial order was randomized across participants using a web-based application (http://www.randomizer.org). A familiarization visit was completed before any experimental testing. This visit required the participants to exercise on a treadmill for 15 minutes at an intensity that yielded a rating of perceived exertion (RPE) of 13 ("somewhat hard") (5). This allowed participants to become familiar with the demands of the exercise and measurement procedures that would be completed in the subsequent experimental session. Participants were asked to consume similar meals the day before each trial, but nutritional intake was not recorded or analyzed.

Participants

Recreationally active women (n = 12) and men (n = 13) (age = 22.0 ± 2.0 yr; BMI = 24.3 ± 3.3 $kg \cdot m^{-2}$) were recruited from a university in Southern California to take part in this within-subjects crossover study. Participants were considered recreationally active if they participated in sports and/or exercise for at least 3 days comprising 120 minutes per week. Participants were excluded if they were smokers or had any mobility issues preventing them from performing the required exercise. All participants completed a PAR-Q and a health history questionnaire to ensure they were healthy.

Protocol

Heart rate and gas exchange data: Heart rate was recorded continuously using an T31 heart rate receiver/transmitter (Polar Inc., Finland), and oxygen uptake (VO_2) and respiratory exchange ratio (RER) were recorded at 15 second intervals with a metabolic cart (ParvoMedics TrueOne 2400, Salt Lake City, UT).

Psychological measures: Immediately pre-exercise and every 10% of work completed, RPE, affective valence, and affective arousal were recorded using Borg's Rating of Perceived Exertion (5), the Feeling Scale (20), and the Felt Arousal Scale (43), respectively. Criterion validity for the Rating of Perceived Exertion is well-established (6). The Feeling and Felt Arousal scales were chosen based on their correspondence to the conceptual framework of core affect (39, 40) and ability to provide strong temporal resolution with minimal participant burden (48). Two- and five-minutes post-exercise, affective valence was also recorded. Finally, 15 minutes after exercise, exercise enjoyment (24) was recorded using the Physical Activity Enjoyment Scale (PACES; Kenzierski and DeCarlo, 1991). Internal consistency of the PACES in the present sample was good (Cronbach's α = 0.88 and 0.83, in the fasted and fed conditions, respectively).

Blood glucose and lactate concentration: Blood glucose (BG) concentration was recorded from capillary glucose samples (Contour Next, Bayer Healthcare, LLC, Milwaukee, WI, USA) upon arrival (-30 minutes), pre-exercise (-5 minutes), post-exercise, and 5 minutes post-exercise. Blood lactate (BLa) concentration (Lactate Plus, Nova Biomedical, Waltham, MA, USA) was recorded from capillary lactate samples upon arrival, immediately post-exercise, and 5 minutes post-exercise.

Statistical Analysis

Data are reported as means ± standard deviation (SD) and were analyzed using SPSS version 24, Chicago, IL, USA). Due to the fact that data were collected as part of a class project, an a priori power analysis was not conducted. A post-hoc analysis, based on the observed effect size f = 0.33 for a two-way (time*condition) within-factors repeated-measures ANOVA on affective valence, revealed a sample of 20 participants was sufficient at an 80% power level and alpha of 0.05 (G*Power 3) (17). A two-way repeated-measures analyses of variance examined changes in variables (heart rate, BG, BLa, gas exchange data, affective valence, and arousal) over time and between FED and FAST, with the Bonferroni post-hoc adjustment used if significant main effects were detected. Mauchly's test of sphericity was utilized to determine if sphericity was violated, with a Greenhouse-Geisser correction applied where appropriate. Data are reported as means ± standard deviation (SD). The difference in enjoyment between conditions was analyzed using a paired t-test. For certain pairwise comparisons, mean differences (MD) and 95% confidence intervals (95% CI) are reported. Statistical significance was accepted as $p < 0.05$.

RESULTS

Exercise responses between conditions were similar and are shown in Table 1. Exercise was completed at an RPE of 13 ("somewhat hard") and elicited an intensity equal to ~88% of age-predicted heart rate maximum (44). Distance covered was estimated from mean treadmill speeds and calculated for each participant. Distance was not significantly different, but participants did cover an additional 69 meters (95% CI: -89.4 – 228 meters; +1.67 %) in the FED condition. Results showed no difference in any measure between exercise in FED and FAST. RER values revealed heavy reliance on carbohydrate as 87 - 90 % of all energy stemmed from carbohydrate utilization in both conditions.

Table 1. Exercise responses during exercise in the fed and fasted state.

	FED	FAST	*p*-value*
Mean VO_2 ($L \cdot min^{-1}$)	2.22 ± 0.65	2.19 ± 0.70	0.54
RER	0.97 ± 0.04	0.96 ± 0.05	0.29
Energy expenditure (kcal)	328 ± 104	332 ± 98	0.54
Heart rate ($b \cdot min^{-1}$)	172 ± 12	170 ± 15	0.35
Treadmill speed ($km \cdot h^{-1}$)	8.25 ± 2.27	8.11 ± 2.17	0.38
Treadmill incline (%)	0.9 ± 2.0	1.0 ± 2.0	0.38
Estimated distance covered (meters)	4134 ± 1140	4065 ± 1088	0.38

*P-value from paired-samples *t*-test. VO_2 = oxygen uptake; RER = respiratory exchange ratio

Psychological responses: Psychological responses to exercise are shown in Figure 1. Affective valence showed a main effect of time ($F_{1.80, 43.08} = 16.37$, $p < 0.001$) as it decreased as exercise progressed but rebounded in recovery. There was no main effect of condition ($F_{1,24} = 2.66$, $p = 0.12$) or a condition*time interaction ($F_{4.86, 116.70} = 1.53$, $p = 0.19$). Arousal displayed a main effect of condition ($F_{1,23} = 8.88$, $p = 0.007$), but no effect of time ($F_{1.62, 38.89} = 1.14$, $p = 0.34$) or condition*time interaction ($F_{3.54, 81.31} = 1.52$, $p = 0.21$). Mean arousal was lower during FED than FAST (MD = 0.35, 95% CI: 0.11 – 0.60). Exercise enjoyment was not different ($t_{15} = -1.27$, $p = 0.223$) between FED (81 ± 11) versus FAST (85 ± 13).

Blood glucose and blood lactate concentration: Changes in BG and BLa concentrations across trials are shown in Figure 2. Blood glucose revealed a significant main effect of time ($F_{2.08, 49.87} = 20.85$, $p < 0.0001$), no effect of condition ($F_{1,24} = 0.41$, $p = 0.53$), and a significant time*condition interaction ($F_{1.55, 37.16} = 55.36$, $p < 0.0001$). Post-hoc analyses revealed that blood glucose was higher pre-exercise in FED (MD = 2.3 $mmol \cdot L^{-1}$, 95% CI: 1.79 – 4.49) and higher post- (MD = 1.16 $mmol \cdot L^{-1}$, 95% CI: 0.67 – 1.64) and 5 minutes post-exercise (MD = 0.89 $mmol \cdot L^{-1}$, 95% CI: 0.43 – 1.35) in FAST (all $p < 0.001$ after Bonferroni correction). Results indicated a significant main effect of time ($F_{1.16, 20.99} = 26.31$, $p < 0.0001$), condition ($F_{1, 18} = 5.26$, $p = 0.03$), and time*condition interaction ($F_{1.38, 24.84} = 4.91$, $p = 0.03$) for BLa. Post-hoc testing revealed higher BLa in FAST compared to FED (MD = 0.65 $mmol \cdot L^{-1}$, 95% CI: 0.05 – 1.24). Specifically, post-exercise blood lactate concentration (MD = 1.23 $mmol \cdot L^{-1}$, 95% CI: 0.378 – 2.08; $p = 0.007$) was higher in FAST compared with FED. Blood lactate concentration was also higher in FAST compared with FED at 5 minutes post-exercise but this was not statistically significant (MD = 0.73 $mmol \cdot L^{-1}$, 95% CI: 0.14 - 1.6; $p = 0.10$).

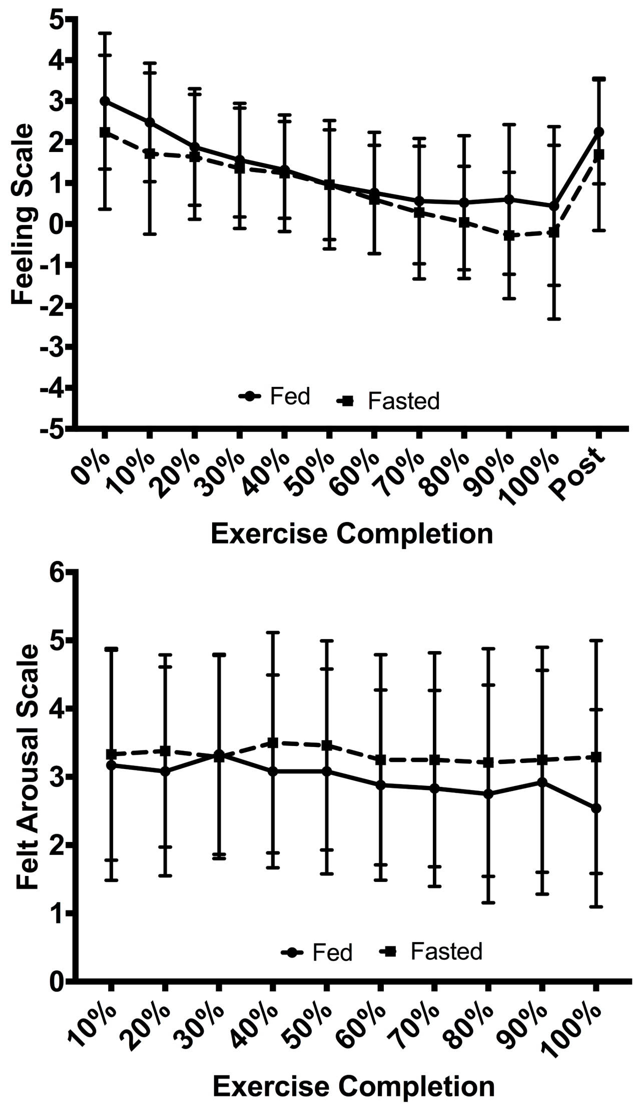

Figure 1. Change in affective valence (top panel) and arousal (bottom panel) during and after exercise. Solid line with circles represents the FED trial while dashed line with triangles represents the FAST trial. Data are mean ± SD.

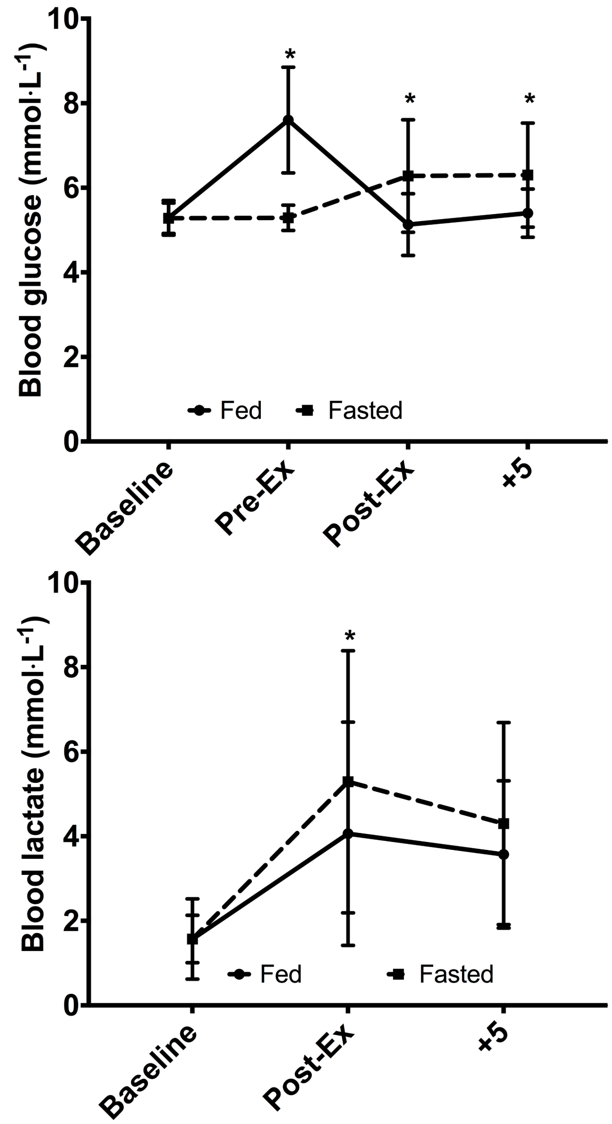

Figure 2. Change in Blood glucose (top panel) and lactate concentration (bottom panel) before and after exercise. Solid line with circles represents the FED trial while dashed line with triangles represents the FAST trial. Data are mean ± SD.

DISCUSSION

The primary aim of the present study was to examine if fed state influences self-selected exercise intensity, affective valence, and perceived exercise enjoyment. Results indicated that a small (180 kcal) carbohydrate rich meal ingested 30 minutes pre-exercise did not influence affect during exercise or perceived enjoyment post-exercise. Despite no differences in psychological variables as well as HR, VO_2, and calorie expenditure, post-exercise blood lactate and glucose were higher in FAST versus FED, potentially indicating a higher metabolic strain despite matched relative intensities.

To our knowledge, this is the first study to report the effects of fasting on affective valence, affective arousal, and perceived exertion during exercise. Previously, Backhouse and colleagues (2005) examined the effect of acute nutritional manipulation on both "how" (affective valence) and "what" participants feel (RPE) during and after prolonged exercise with carbohydrate ingestion (3). Their data demonstrated significantly higher affective valence during exercise with carbohydrate ingestion versus a placebo, despite no change in RPE (3). In another study, Rollo and colleagues (2008) required trained men to exercise for 30 min at a speed corresponding to an RPE of 15 ("hard") with or without carbohydrate mouth-rinsing. Their results demonstrated that mouth rinsing enhanced running speed during the initial 5 minute segment, led to more distance covered (+1.7 %); and was associated with a higher pre-exercise affective valence, although there was no difference in affective valence during exercise (38). Our results differ from these findings due to some methodological differences across studies. First, Backhouse et al. and Rollo et al. required carbohydrate intake much closer to and during exercise (1, 38). Second, Rollo et al. utilized a radar-controlled treadmill which automatically adjusts speed based upon the position of the runner on the treadmill belt (38). In our study, change in speed or grade required a conscious decision on the part of the participant. Finally, it is worth considering that the total amount of carbohydrate ingested in prior studies was higher than that of the present study, since they were conducted in line with sports nutrition guidelines (43-80 g CHO) (1, 3, 13). It is also worth noting that our participants had 30 minutes between energy intake and exercise, in order to minimize gastrointestinal distress. Prior research, predominantly using liquid carbohydrate instead of solid food, had much shorter intervals between feeding and exercise (1, 3, 38). Furthermore, the minimal effects of fed versus fasted state on affective valence in the present study corroborates more recent results (37). Overall, effects of carbohydrate ingestion before and during exercise are equivocal, with some researchers reporting reduced or maintained RPE (1-3) and others reporting no effect (13, 37). In addition, the exercise protocols used in previous studies are heterogeneous which lead to different magnitude of calorie expenditure and thus different potential for efficacy of pre-exercise carbohydrate ingestion. Our data contribute to existing literature and indicate that ingestion of a small carbohydrate-rich meal has minimal effect on affective valence, arousal, and perceived exertion.

To our knowledge, this is also the first study to report the effect of fasted state on exercise enjoyment. While affective valence during exercise can be conceptualized to indicate experienced pleasure or utility (23), exercise enjoyment reported *about* exercise *after* exercise is a retrospective evaluation. Moreover, affective valence is conceptualized to represent a dimension of core affect (39, 40), but enjoyment is conceptualized to represent a distinct, valenced emotional state. A strength of the present study is the measurement of these related yet distinct constructs. The data indicate that overnight fasting does not reduce the experienced pleasure or remembered enjoyment of exercise at a self-selected, moderate intensity. This is likely a result of the similar VO_2, energy expenditure, and heart rate exhibited (Table 1). In practical terms, this means that exercisers may be able to exercise "on an empty stomach" without creating unpleasant and unenjoyable experiences that may reduce adherence. However, our results do not apply to prolonged fasting or high-intensity exercise, and further examination is needed to elucidate changes in enjoyment in response to these interventions.

Many of the aforementioned studies included carbohydrate ingestion before and during exercise, which makes direct comparison of blood glucose responses difficult. Carbohydrate ingestion during exercise has been shown to maintain blood glucose levels during exercise and spare muscle glycogen stores by providing exogenous carbohydrates (10). In the present study, despite a similar RER, post-exercise and recovery blood glucose concentration was higher in FAST compared to FED. Although the mechanism explaining this result is beyond the scope of our study, this is potentially due to increased muscle glycogen degradation or gluconeogenesis in order to maintain blood glucose concentration (30). Our results of higher post-exercise glucose in FAST oppose those of a recent meta-analysis; however, most studies reviewed required intensities between 50-75% VO_2max (46), which is lower than the intensity attained in our study. These authors reported various moderators of blood glucose responses, including exercise duration and intensity, sex and BMI, fitness level, time between meal ingestion and initiation of exercise, and quantity of pre-exercise carbohydrate ingested.

Conversely, our data show that post-exercise blood lactate concentration was higher in FAST versus FED despite no differences in affective valence. Prior research showed a lack of association between blood lactate concentration and affective valence (4). In line with our observations of increased blood glucose concentration in FAST, the higher blood lactate concentration in FAST are likely indicative of higher rates of glycolytic energy production, which is supported by the high RER (8). During steady state exercise, blood lactate concentration tends to be similar when carbohydrate is ingested compared to water or placebo (10, 13).

A limitation of the present study is that despite "clamping" RPE, relative intensity was rather high, as illustrated by intensity equal to 88-89% predicted heart-rate maximum and end-exercise blood lactate equal to 4.0 (FED) and 5.2 (FAST) mmol/L. Given the familiarization visit and explanation of RPE, it is unclear why the physiological strain was so high. Another limitation of the current study was that the meal's caloric intake was identical across participants rather than based on body weight. This may have caused a wide variety of perceived gastrointestinal responses related to fullness, bloating, or cramping which were not quantified in the present study. Conceivably, this could have led to increased physiological or perceived strain (12, 35), but given the lack of differences in VO_2 and HR between conditions, this was unlikely.

The present study examined the influence of fed state on perceptual and physiological outcomes during self-selected exercise following current Physical Activity guidelines. Results indicated that fed state did not influence self-selected intensity, affective valence, arousal, or enjoyment. Therefore, our results suggest that for individuals performing exercise in accordance with current guidelines, fed state will not impact variables known to influence exercise adherence such as affective valence or enjoyment of activity. However, these results should not be generalized to prolonged fasting, prolonged exercise, or high-intensity exercise.

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